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ABSTRACT

This document discusses methods of calibration for chemical sprayers to insure proper control of the target plant or insect. Both granular and spray application techniques are presented with special emphasis given to computing chemical mixes properly. (CS)

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Pesticide Application Equipment, Calibration and Maintenance

MP 26
COLLEGE OF AGRICULTURE
AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF WYOMING—LARAMIE
DECEMBER 1973

APPLICATION EQUIPMENT, CALIBRATION AND MAINTENANCE

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TABLE OF CONTENTS

	Page No.
SECTION I - Spray Equipment	V-1
A. Hydraulic Sprayers	V-1
B. Tanks	V-1
C. Tank Agitators	V-3
D. Filters (Screens)	V-4
E. Pressure Regulator	V-4
F. Pressure Gauge	V-4
G. Flow Cutoff Valves	V-4
H. Hoses and Filters	V-5
I. Pumps	V-5
1. Capacity	V-5
2. Pressure	V-5
3. Resistance to corrosion and wear	V-5
4. Repairs	V-5
5. Type of drive	V-5
J. Nozzles	V-7
1. Nozzle delivery	V-9
2. Spray tip wear	V-9
SECTION II - Granular Applicators	V-13
A. Factors Affecting Application Rate	V-13
B. Variation in Granules	V-13
C. Maintaining Proper Speed	V-14
D. Granular Spreaders	V-14
SECTION III - Calibrating Chemical Applicators	V-15
A. Calibrating Field Sprayers	V-15
1. Pre-calibration preparation	V-15
2. Measuring tank capacity	V-15
a. Dip stick	V-15
b. Float	V-16
c. Sight gauge	V-16
d. Flowmeter	V-16

Table of Contents (con't.)

	Page No.
3. Refill method.	V-16
a. Adjust pressure.	V-16
b. Determine speed.	V-17
c. Measure swath.	V-17
d. Make test run.	V-18
e. Calculate spray rate	V-18
4. Band application	V-18
5. Nozzle method.	V-19
B. Calibrating Hand Sprayers.	V-20
1. Compressed air sprayers.	V-21
2. Pressure hand gun.	V-21
C. Computing Chemical Mixes	V-21
1. Computing mixes as pounds per acre	V-21
2. Figuring solutions as percent.	V-22
3. Figuring solutions as parts per million mix.	V-23
a. Parts per million mix (powder)	V-23
b. Parts per million mix (liquid)	V-23
4. Figuring chemicals for small plot work	V-23
D. Calibrating Granular Applicators	V-25
1. Field calibration.	V-25
2. Shop calibration	V-26
3. Calibrating granular insecticides.	V-26
E. Summary.	V-27
SECTION IV - Sprayer Maintenance and Cleaning	V-29
SECTION V - Aerial Application.	

SECTION I

Spray Equipment

The list of chemicals used in controlling weeds, insects, and diseases in agriculture grows every year. These chemicals are becoming more specific in their control and generally more care is required in their application to obtain satisfactory results. The application of too little or too much of any pesticide, or the application at the wrong time and/or place can result in money loss in chemicals, machine use, and labor. Improper amounts of chemicals and improper timing may also result in unsatisfactory control or even damage to crops or animals.

Chemical manufacturers spend millions of dollars in research to determine the proper application rates which will provide effective control and yet stay within acceptable tollerance levels for residues in the crops or animals treated. Accurate application of pesticides is a major factor in keeping residues within acceptable levels. Unsatisfactory results from chemical treatments are almost always the result of improper use of the chemical or application equipment.

Most agricultural chemicals today are intended to be applied as a liquid spray or as a granular material. Equipment for applying these chemicals must give uniform coverage and be easy to regulate, maintain, and clean.

A. Hydraulic Sprayers

Hydraulic sprayers are in general use on farms and ranches today. They discharge sprays by means of pressure developed by the action of the pump on the liquid spray material. The pressure forces the liquid through nozzles which creates droplets of various sizes and disperses them in the desired spray pattern.

Complete hydraulic sprayer units are available commercially or component parts may be purchased for custom assembly. All agricultural sprayers have essentially the same component parts (see figure 1). These will be discussed individually.

B. Tanks

Many spray materials are corrosive to metals and the resulting rust scales plug the system, block filters, cause excessive wear on the pump, or clog the nozzles. Tanks made of plastic lined steel, stainless steel, or fiberglass are preferred, because they are less subject to corrosion than bare metal tanks. Stainless steel is the preferred material because

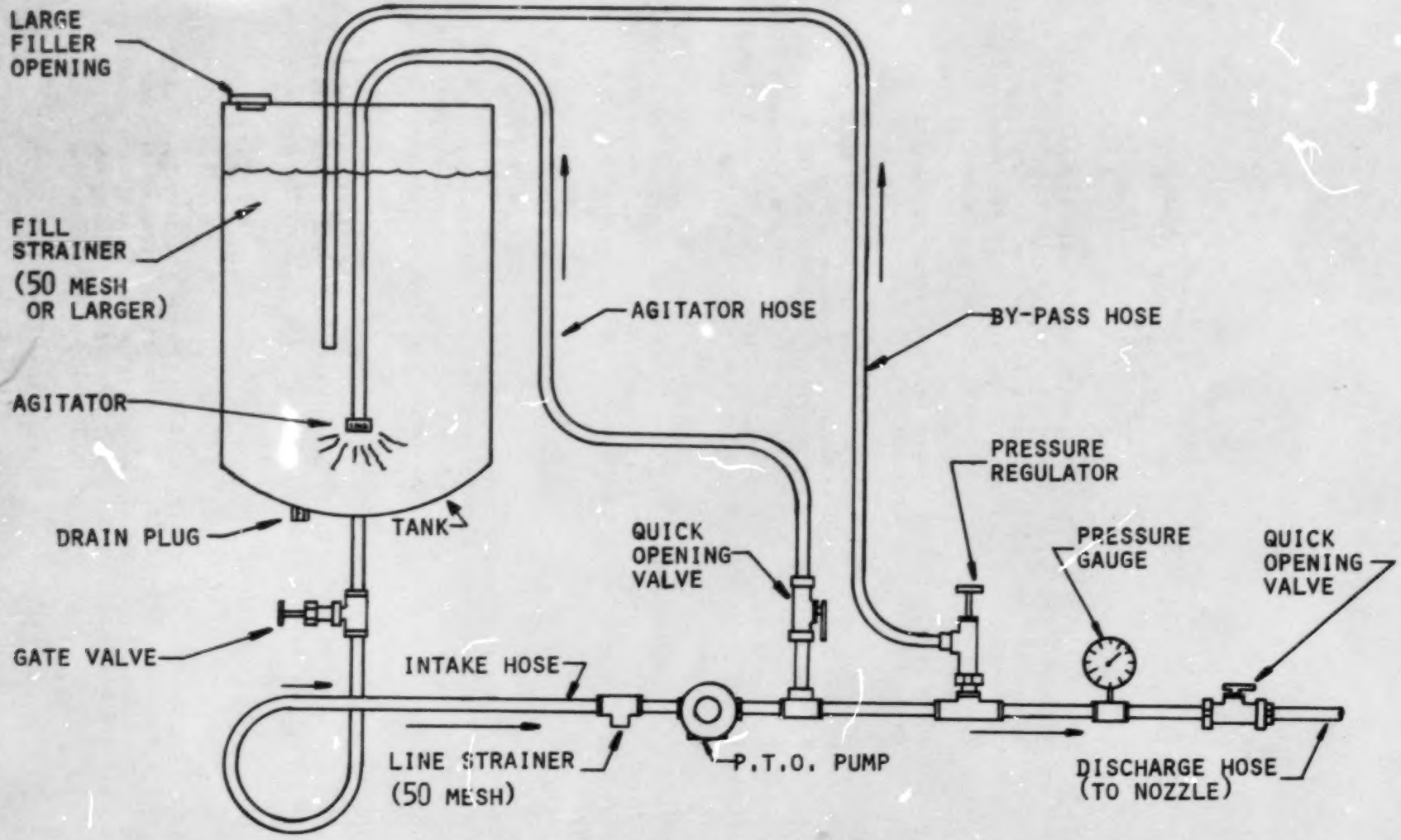


Figure 1. Schematic outline of a sprayer system.

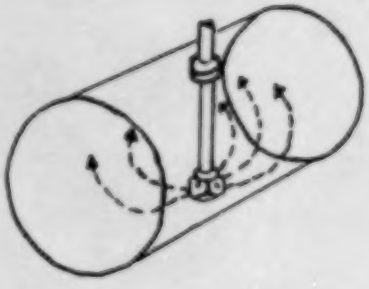
it is more durable and will be most practical and economical over a period of time.

The tank may be of any size but should be matched to the type of job the sprayer will be expected to perform. Tanks should be rounded on the sides and ends, and mounted horizonatally so they can be easily cleaned and drained. A large filler hole with hinged cover should be located on the top of the tank to facilitate easy filling and cleaning. The outlet should be located on the bottom of the tank near the forward end for fast and complete draining.

C. Tank Agitators

Solutions and emulsions can be sufficiently stirred by the return liquid from the regulator by-pass line. Wettable powders require more agitation to keep them in suspension. Mechanical agitation is best, but where this is not practical, hydraulic jet agitation should be used.

Jet agitators use liquid from the sprayer's pressure system. The line to the agitator should be connected between the pump and any cutoff valves to the nozzles so agitation will continue when spraying is momentarily stopped as for turning.



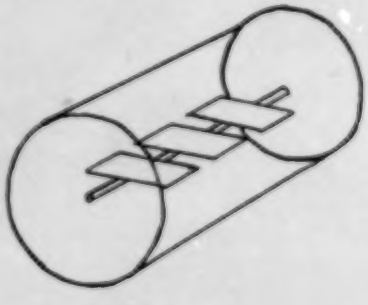
Jet diameters must be large enough to provide a minimum flow of 3 gallons per minute for each 100 gallons of tank capacity. Table 1 lists the capacity in gallons per minute for different hole sizes.

TABLE 1. Flow through jet agitators at 35 psi.

Hole size (inches)	1/16	3/32	1/8	5/32
Gallons per minute	1.00	1.45	2.55	3.84

Be sure the discharge from the jet agitator passes through approximately 12 inches of solution before striking the side of the tank. A high velocity jet stream of wettable powder or suspensions will wear a hole in the tank unless it passes through sufficient solution.

Mechanical agitation is accomplished by paddles or a propeller revolving in the tank. This type of agitation is difficult to secure in tractor or trailer mounted sprayers, since the tractor power takeoff is used to operate the pump and would be difficult to attach to an agitator. Mechanical agitation usually is built into sprayers that employ auxiliary engines for power.



D. Filters (Screens)

Filters or screens are an essential part of the spraying system. Screens are normally placed at the entrance to the pump intake line, in the line from the pressure regulator to the boom, and in each nozzle. The mesh or size of the screens on the filters should be large enough to allow passage of wettable powders (50 mesh) and emulsifiable liquid concentrates (100 mesh). Mesh refers to the number of openings per linear inch of the screen material. The screens in the nozzle tip should be sized according to the opening in the nozzle. Filters should be checked and cleaned often to prevent poor coverage and loss of pressure.

E. Pressure Regulator

The pressure regulator or relief valve maintains the required pressure in the system. It is a spring-loaded valve that opens to prevent excess pressure in the line and returns some of the solution to the tank. Most pressure regulators are adjustable to permit changes in the working pressure, if desired.

F. Pressure Gauge

Accurate pressure measurement is important since pressure is one factor which can be controlled and may determine the amount of liquid being sprayed. Spray nozzles are designed to operate within certain pressure limits. High pressures can cause dangerous fogging and drift, while low pressures may increase droplet size to the point that improper coverage is obtained.

The gauge will indicate malfunction by showing fluctuations in pressures. Rapid fluctuations of the gauge may occur when roller pumps are operated at low speed. This condition may be corrected by installing a damper ahead of the gauge. Pressure gauges should be selected to give accurate readings within the range of pressures normally used in the spraying system. For example; don't use a 300 psi gauge on a system that normally operates at 35 psi. Accurate readings would be virtually impossible with this type of equipment. The pressure gauge is a delicate instrument and should be handled with care. Check its accuracy periodically to assure proper operating pressures.

G. Flow Cutoff Valves

Place a quick acting valve or valves between the pressure regulator and the boom to control the flow of spray materials. One valve may be used to cut off the flow to the entire system, or a combination of two or three valves may be used to control flow to one or more sections of the boom. Special selector valves are available which control the flow of spary materials to any section of the boom. The flow cutoff valve should be easily accessible to the operator and is usually located close to the pressure regulator.

H. Hoses and Fittings

A good hose is flexible, durable, and resistant to sunlight, oil, chemicals, and the general abuse given to a hose during sprayer operation. Oil base chemicals cause deterioration of regular rubber hose; therefore, hoses made of neoprene or other oil resistant materials are recommended.

The hose size varies with the pump capacities involved; however, the suction hose should be larger than the pressure hoses. Usually the suction hose will be 3/4 to 1 inch in diameter and is reinforced to prevent collapsing under vacuum.

Pressures are often encountered which are much higher than the average operating pressures. Hoses on the pressure side of the system should be reinforced to prevent accidental breaking, which could cover the operator with injurious spray material. Fittings, including clamps, should be designed for quick, easy attachment and removal.

I. Pumps

There are many types of pumps on the market with advantages and disadvantages specific to each pump. The most important factors to consider in selecting a pump are as follows:

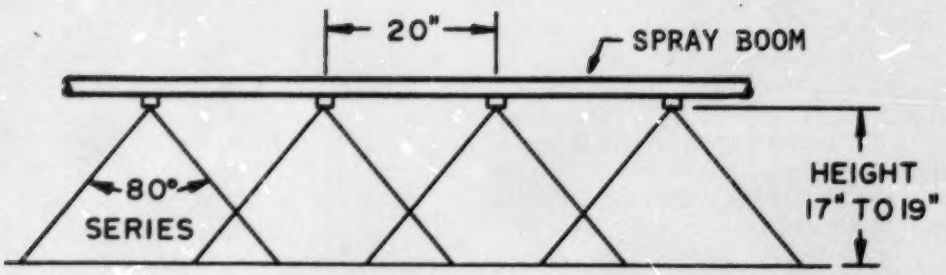
1) *Capacity.* The pump should be of sufficient capacity to supply the boom output and provide for by-pass agitation. The boom output is calculated from the number and size of nozzles used. See figure 2 for information on nozzle capacities. Hydraulic agitation, if used, should be added to the boom output. Select a pump which will provide the boom output plus about 50% more for agitation through the by-pass return. Pump capacities are given in gallons per hour (gph) or gallons per minute (gpm).

2) *Pressure.* The pump must be able to produce a desired operating pressure at the capacity required for the spraying job to be done. The amount of pressure is indicated in pounds per square inch (psi). Some pumps designated as low pressure can produce high pressure but will wear out rapidly if operated under high pressure conditions.

3) *Resistance to corrosion and wear.* The pump must be able to handle the chemical spray materials without excessive corrosion or wear. Some pumps will handle abrasive materials like wettable powders with much less wear than others. Chemical reaction and corrosion affects certain materials more than others.

4) *Repairs.* Pumps should be designed so that repairs can be made economically and quickly.

5) *Type of drive.* The pump should be readily adaptable to the available power source. The average farm tractor does not have a high speed power takeoff unit, and therefore is not adapted to pumps designed to operate faster than 500 to 1,000 rpm. High speed pumps will require an auxiliary power source or speed increaser. Roller



TIP NO.	PRESS IN PSI	CAP IN GPM	GALLONS PER ACRE					
			2 MPH	3 MPH	4 MPH	5 MPH	7.5 MPH	10 MPH
8004 (*26GPA) (50 MESH)	20	.28	43	28	21	16.8	11.2	8.4
	25	.32	47	31	24	18.7	12.5	9.4
	30	.35	51	34	*26	21	13.7	10.3
	40	.40	59	40	30	24	15.8	11.9
	50	.45	66	44	33	27	17.7	13.3
	60	.49	73	49	36	29	19.4	14.6

Figure 2. Nozzle capacity chart.**

*Standard or average operating condition.
**From Spraying Systems (Teejet) Catalog No. 35.

pumps can be attached directly to the tractor power takeoff but should be secured with a chain to prevent the case from rotating.

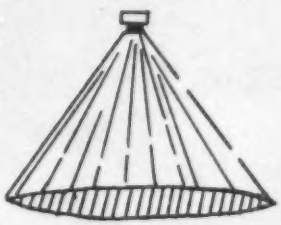
Table 2 summarizes various types of pumps used for agricultural spraying a lists some of their important characteristics.

J. Nozzles

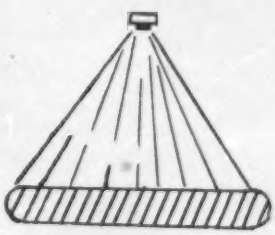
The nozzle is one of the most important parts of the sprayer. Nozzles should be selected to give the proper range of droplet size, spray pattern, and application rate within the recommended range of operating pressures. Manufacturers rate each nozzle in gallons per minute and gallons per acre at specified pressure and ground speeds. These two factors can be varied, within limits, to change the application rate.

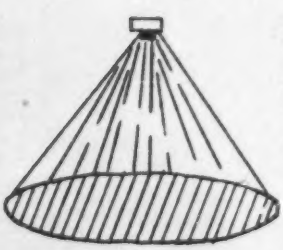
Pressure which is too high for a given nozzle results in small droplets and a distorted spray pattern. Excessive drift is a symptom of too high pressure. Pressure which is too low results in large droplets and an in complete spray pattern and uneven coverage.

The *flat spray nozzle* is used most often for weed control. It produces a fan shaped pattern of medium droplet size. When evenly spaced on a broadcast boom and operated at the proper height the fans overlap to obtain even coverage. It is suitable for insect control where penetration of the foliage is not necessary. Wide angle nozzles of this type can be operated close to the ground to limit drift.



The *even spray nozzle* produces a fan spray but with a more uniform spray pattern across the entire width of the fan than the falt spray nozzle. It is used for band spraying in row crops where there is no overlap from adjacent nozzles.





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Cone nozzles give a smaller droplet size than flat or even spray nozzles and are used for insect and disease control, where penetration of the foliage is desirable and drifting is not objectionable. These nozzles are usually operated at 60 psi pressures or higher.

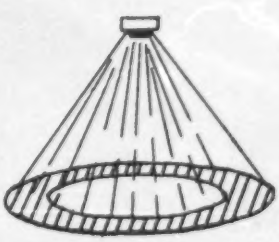

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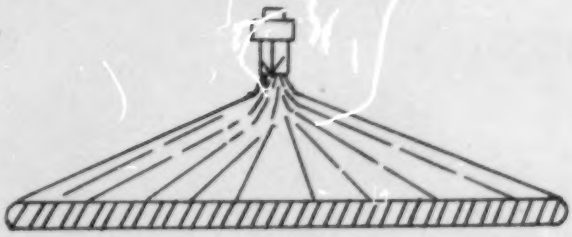
TABLE 2. Summary of the various types of pumps used for agricultural spraying.

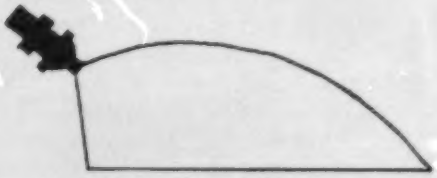
	Piston	Gear	Roller impeller	Diaphragm	Irternal gear	Centrifugal
1. Adaptability: (Handle corrosive or abrasive materials.)	Wide range of application. Will handle corrosive and abrasive materials.	Oil emulsion, non-abrasive materials. Cannot be used with wettable powders.	Oil emulsions and non-abrasive material. No copper compounds. Rubber rollers for slurries and wettable powders.	Will handle all chemicals which will not attack diaphragm.	Will not handle abrasives.	Will handle coarse and abrasive materials.
2. Durability	Basic parts have long life.	Limited life under adverse conditions.	Pressure drops with wear	Maintains pressure with wear.	Cannot operate dry. Pressure drops with wear rapidly.	Pressure drops with wear.
3. Cost	$75 to $300	$25 to $50	$35 to $75	$60 to $200	$40 to $75	$30 to $60
4. Serviceability	Readily serviced.	Parts not usually replaced. Pump readily replaced.	Special technique in servicing. Worn parts can be replaced.	Readily disassembled for service.	Parts readily changed.	Certain models can be serviced.
5. Construction (critical parts)	Cylinders ceramic; stainless steel; bronze.	Bronze gears, stainless steel shaft.	Rollers-nylon or rubber. Case-nickel, cast iron.	Rubber or synthetic diaphragm.	Nickel cast iron and stainless steel shaft.	Case: Cast iron or plastic. Impellers: Cast iron, bronze and plastic.
6. Pressure range	0 - 1000 psi.	0 - 100 psi.	0 - 150 psi.	0 - 150 psi	0 - 120 psi.	0 - 50 psi.
7. R.P.M. (operating range)	500 to 1000	500 to 1800	300 to 1000	500 to 800	500 to 600	1200 to 3500
8. Discharge capacity	3 - 10	0 - 65	5 - 50	3 - 10	0 - 100	0 - 100
9. Required horsepower	2 to 6 hp	1/6 to 4 hp	1/2 to 5 hp	5 to 3 hp	1/6 to 4 hp	1/4 to 3 hp

*Adapted from Extension Reference Manual--Southern Region--Pesticides; Henry O'Neil, 1972.

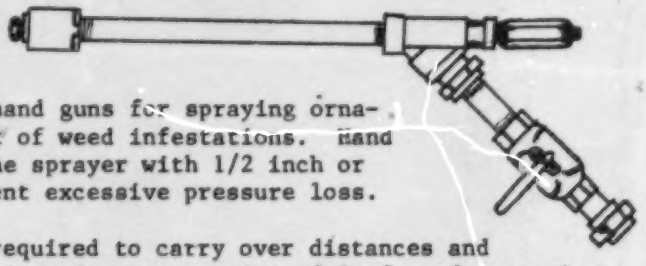
The *flooding spray nozzle* produces a wide pattern and is used close to the ground. It operates at low pressure and the danger from drift is very low. It is used most commonly for weed control work.



Boomless or off-set nozzles direct spray to one side of the nozzle only. They are used for special applications such as roadside or irrigation ditch weed control. Small nozzles may be used to extend boom coverage and larger nozzles for side spraying up to 30 foot swaths. Coverage is not as uniform as with other nozzle types. Some manufacturers offer cluster assemblies with two or more off-set nozzles for spraying both sides from the sprayer.



Hand guns may be attached to spray systems for remote spraying. Commercial spray applicators often use hand guns for spraying ornamentals or for spot treatment of weed infestations. Hand guns should be attached to the sprayer with 1/2 inch or larger diameter hose to prevent excessive pressure loss.



A large droplet size is required to carry over distances and reduce drift. This may not give adequate wetting of leaf surfaces unless excessive amounts of spray are used. A nozzle producing finer spray will lack carrying power and increase drift problems. Adjustable hand guns are available, however, so that the spray pattern can be tailored to the job.

1) *Nozzle delivery.* Spray tips come in a wide variety of sizes and spray patterns. Tip capacity is rated in gallons per minute at a given pressure. Spray patterns vary from 65 to 160 degrees. A typical manufacturers catalog listing is shown in figure 2. Select tips to give the desired coverage at the speed and pressure selected for the spray job. Manufacturers may indicate a standard or most effective spray rate for each spray tip. This rate represents the capacity under average conditions.

2) *Spray tip wear.* Spray tips wear during use and require rather close attention if chemical application is to remain accurate over a period of time. The rate at which nozzles wear is influenced by the material from which they are made. A ranking of these materials for wear resistance from least to most would be about as follows: Aluminum, brass, stainless steel, hardened stainless steel, chrome plated brass, and nylon.

Generally speaking, the greater the wear resistance the more the initial cost. The greater cost, however, may be justified by increased tip life, reduced maintenance, and more accurate application of spray materials.

Abrasive compounds like wettable powders greatly increase tip wear. Also, smaller tips tend to wear at a faster rate than larger ones. A comparison of wear on brass, stainless steel, and chrome plated brass tips when spraying a wettable powder is shown in figure 3.

It should be noted that a rapid increase in delivery due to wear occurs in the first hour of operation. Even though manufacturers exercise a great deal of care in the tip manufacturing, there are apparently rough edges in the orifice which are quickly removed in use. Brass tips should be recalibrated after 2 hours of use and again every 8 or 10 hours thereafter to insure accurate chemical application. More wear resistant tips should be recalibrated every 20 to 30 hours.

Nozzle wear not only increases the delivery rate but the spray pattern may also be affected. Nozzle tips showing a 20% increase in delivery rate over design capacity should be replaced.

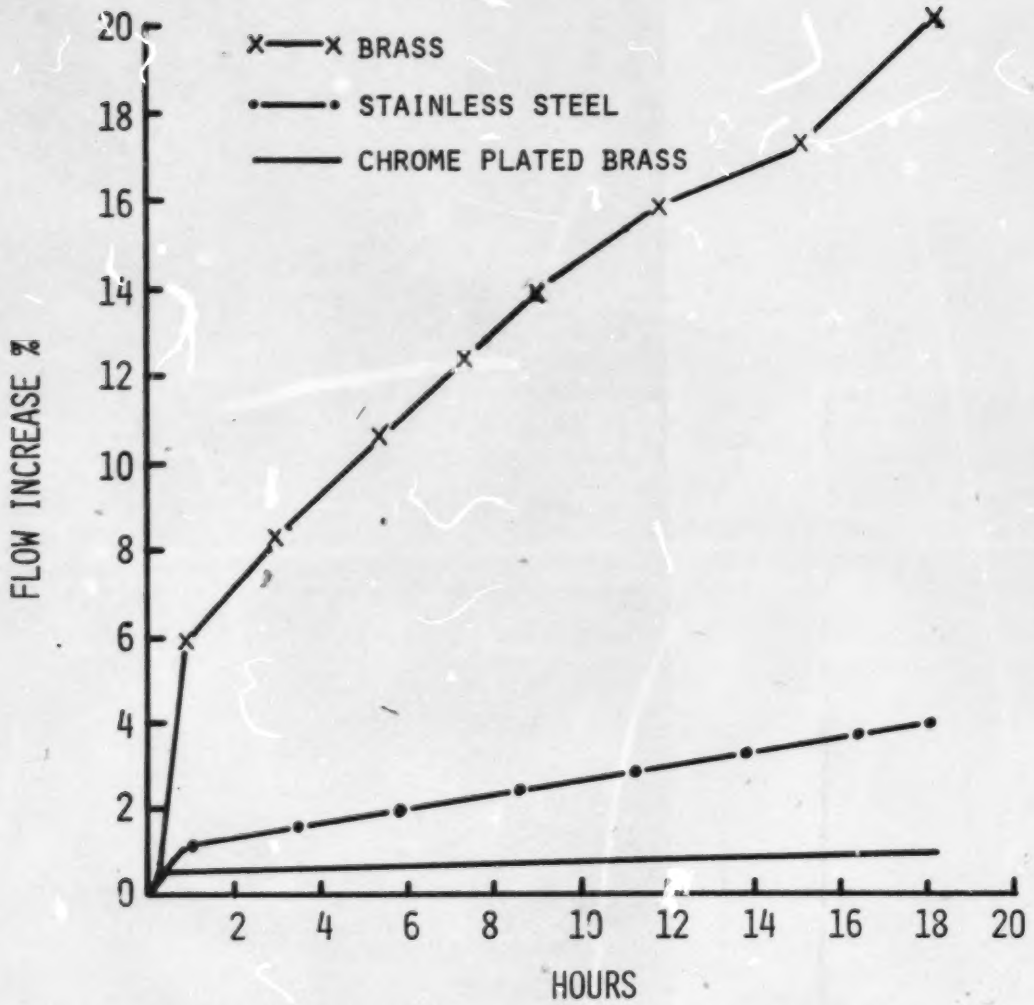


Figure 3. Progressive wear of brass, stainless steel, and chrome plated brass nozzles after spraying 1.6 pounds of diuron WP and 1 pint of surfactant in 25 gallons of water. (Wooten, O. B., et.al Effects of Diuron on Wear of Spray Nozzles, ARS 42-91, Nov., 1963.)

SECTION II

Granular Applicators

A number of herbicides and insecticides are marketed in granular form. This is particularly true of preemergence herbicides and soil insecticides. These chemicals must be applied with precision. Application of less than the recommended rate may result in ineffective control; while application of more than the recommended rate will increase costs and may damage the present or subsequent crops.

Both insecticides and herbicides may be broadcast before or after planting. It is a common practice, however, to apply granular pesticides in a band over the row by attaching applicators to the planter. Application equipment consists of a metering device and a spreading device to provide a uniform distribution of the chemical across the treated band.

A. Factors Affecting Application Rate

Most granular applicators (meters) consist of a hopper with a rotating agitator for metering the granules through an adjustable orifice. Several factors can cause a variation in the application rate, including the following:

1) Exposed area of the metering orifice

2) Speed of the agitator

3) Ground speed of the applicator

4) Nature and size of the granules

5) Roughness of the field

6) Humidity

7) Temperature

B. Variation in Granules

Many granules look alike but there is a wide variation in the size and density of the particles and the nature of the inert material on which the chemical is impregnated. For these reasons, a different orifice setting is needed for each chemical applied. In addition, a different setting may be required for the same chemical formulated by different manufacturers, and sometimes for different batches by the same manufacturer. The appli-

cator will have to be calibrated for every chemical used and again each time a new supply is purchased.

C. Maintaining Proper Speed

Most granular applicators are ground driven. Changes in ground speed change the speed of the agitator which in turn affects the application rate. As the speed of the agitator increases, the application rate may increase *but not in the same proportion.* Therefore, applicators must be calibrated at the ground speed to be used in the field or, in the case of pto driven applicators, at the same engine speed that will be used in the field.

High agitator speed may result in excessive grinding of the granules which will cause the application rate to vary with time as the hopper empties. The recommended speed for vane type agitators is usually between 10 and 20 rpm.

Information on determining ground speed and calibration of granular applicators will be covered in more detail in the calibration section of this manual.

D. Granular Spreaders

Spreader devices are usually fan shaped with an internal device for distributing the granules uniformly across the band. The usual width of the spreader is 6 inches and they are used singly or in pairs depending on the desired band width. The spreader is connected by flexible tubing to the metering unit and the granules flow from the meter to the spreader by gravity. The connecting tubing should be kept as straight as possible to prevent uneven distribution of granules on the band and also to prevent plugging.

Soil insecticides are usually spread in a narrow band over the top of the seed. Band width should be 4 to 7 inches or as recommended on the chemical label. The amount of incorporation needed for soil insecticides is a function of plant, insect, insecticide, and timing and is still being researched. At present it would appear the recommended practice would be to spread insecticides behind the planter using a drag chain for light incorporation. Avoid concentrating the insecticide around the seed.

Preplant herbicides are also placed in a narrow band over the row but, unlike insecticides, best results are obtained when the herbicide is incorporated into the top 1 to 1-1/2 inches of soil. Because of the incorporation requirement, herbicides are usually spread and incorporated ahead of the planter. Powered rotary incorporators give the best results, but other methods of mixing the chemical into the soil are used. A general practice is to treat a 6 or 7 inch band narrow (22 inch - 24 inch) crop rows and 12 to 14 inch treated bands are used with wide (30 inch - 40 inch) crop rows.

SECTION III

Calibrating Chemical Applicators

Most pesticides must be applied at very precise rates if satisfactory results are to be obtained. Applying too little will result in poor control while too much pesticide may injure crops and livestock or produce unwanted residues which make soils, plants, or animal tissues unusable. *Correct application rate is one factor which the operator can control.*

To know how much chemical to add to your sprayer tank you must first know how many acres the carrier, usually water, in your tank will spray with your particular pressure, nozzles, pumping arrangement and operating speed. That's what calibration tells you.

A. Calibrating Field Sprayers

There are two basic ways to calibrate field sprayers, the refill or field trial method and the nozzle method. Within each method there are several variations in the actual steps and calculations. One way of calibrating using each method will be discussed in this paper. Other procedures not discussed may be just as accurate or easy. It is important to pick a procedure you understand and use it each time you apply chemicals.

1) *Pre-Calibration Preparation.* Before you go to the field, service the entire sprayer and determine exactly how much liquid the sprayer tank holds regardless of which calibration method you choose. Clean all lines and strainers. Make sure all strainers are the correct size and properly placed. Check each nozzle flow for 30 seconds into a marked container, a baby bottle or measuring cup marked in ounces will do. Clean or replace nozzles where uneven flow is noted. Nozzle delivery shouldn't vary more than 10% from the highest to the lowest. *Never* use a metal object to clean nozzles.

2) *Measuring Tank Capacity.* Determining how much liquid the tank holds may seem simple, but it's where many mistakes are made. Dont' believe anybody else -- find out for yourself. If the tank does not have an effective liquid level gauge, there are three ways to measure the tank's capacity.

a. *Dip stick.* Be sure the tank is empty and level when you start. Use any convenient container, but know its exact capacity. For example, a "5 gallon" bucket should be measured to determine exactly how much it holds. Use the measured bucket or container to fill the tank. As it fills, mark each convenient quantity level on a dip stick. Be sure to note where the dip stick goes in, and insert in exactly the same place

each time. On a big tank, 5 gallon marks may be too close together. If so space the marks at larger intervals.

b. *Float.* A simple float can be attached to the dip stick to show the liquid level in the tank during operation as well as for determining capacity. Attach a plastic or styrofoam float to the dip stick, drill a hole in the tank filler cap to allow the dip stick to move up and down. A guide about an inch long in the cap will prevent the rod from binding. This works best if the float is placed in the center of the tank.

c. *Sight gauge.* New regulations require a simple plastic tube sight gauge. One can be made or replaced as shown if missing, clouded, or plugged. Use the bucket fill method described under "*Dip stick*" to mark the quantities on the sight gauge. The tank must be exactly level if the sight gauge is mounted on the end of the tank for accurate calibration or reading.

d. *Flowmeter.* Attach flowmeter to filling hose to measure quantity of water as it goes into tank. Good flowmeters are available at a modest price. If you do use one to check how much the tank holds, this would be a good time to calibrate the sight gauge, since you can mark the measured volumes as you fill the tank.

Important--Regardless of how you measure it, the important thing is to know exactly how much water is in the tank.

3) *Refill Method.* The refill or field trial method of calibrating is the most common and easiest method to understand. It also has the most variations in the way it is done. This method of calibration should always be done in the field, not on a road or in the driveway. Field conditions can seriously affect sprayer speed which in turn affects spray rate. The steps for using the refill method are summarized as follows:

Step 1. Fill the spray tank with water;

Step 2. Adjust pressure within recommended range for nozzles used;

Step 3. Select an easily maintained speed that fits the field conditions;

Step 4. Spray a measured area;

Step 5. Return to filling point and measure the amount of water needed to refill the spray tank;

Step 6. Calculate the spray rate.

a. *Adjust pressure.* Adjust the pressure to the recommended level. Most nozzles used on field sprayers work best between 20 and 40 pounds per square inch pressure (psi). Below 20 psi the spray pattern may be distorted. Pressures above 40 psi tend to increase spray drift and may damage non target species. The manufacturer's catalog gives the recommended or standard pressure for each of its nozzle tips.

Slight increases or decreases in spray rate can be made by changing the pressure within the recommended range. Nozzle discharge varies with the square root of pressure. Doubling the pressure will increase nozzle delivery 1.4 times (example $\sqrt{40} \div \sqrt{20} = 1.4$). Major changes in delivery rate should be made by changing nozzles or by adjusting speed.

b. *Determine speed.* Field conditions have a marked affect on speed which can seriously change spray delivery. A sprayer calibrated at 4 mph and driven at 3 mph will overspray 25% for example.

To determine field speed, measure a course in the field equal to 88 feet or a multiple of 88 feet. Traveling 88 feet in 1 minute, is equal to 1 mph. Operate the sprayer over the course and note the time needed. Calculate your speed by multiplying 60 by the multiple of 88 feet traveled and divide by the number of seconds needed to drive the course.

EXAMPLE

If it takes 24 seconds to go 88 feet, your speed is: $\frac{60 \times 1}{24} = 2\frac{1}{2}$ mph. At speed over 4 mph, using 2 or 3 multiples of 88 feet will give more accurate speed determination. (Table 1.)

Table 1. Time (seconds) required to travel multiples of 88 feet at different field speeds.

Multiple (distance traveled)	Speed-miles per hour						
	2	3	4	5	6	8	10
1 - (88 feet)	30	20	15	12	10	7.5	6
2 - (176 feet)	60	40	30	24	20	15	12
3 - (264 feet)	90	60	45	36	30	22.5	18

Adjust your throttle to get the desired speed and mark throttle setting or use a positive throttle stop so your speed will always be the same. A tachometer is very useful for adjusting ground speed or for maintaining a pre-selected speed particularly when the sprayer is mounted on a truck. A truck speedometer is not accurate enough for spraying or calibration.

c. *Measure swath.* You next need to measure the sprayed swath width (not the boom length). Use a long tape measure or multiply the nozzle spacing on the boom by the number of nozzles. You must divide by 12 to get the answer into feet if you measured nozzle spacing in inches.

EXAMPLE

Your boom has 18 nozzles spaced 20 inches apart. Your swath width is $\frac{20 \times 18}{12} = 30$ ft.

Measure off a convenient distance in the field to use for a calibration run. There are 43,560 square feet in an acre. The distance needed to spray 1 acre can be determined by dividing 43,560 by the swath width. If that distance is too long for convenience, any known distance can be used and the spray rate calculated.

d. *Make test run.* The final step is to spray the measured distance and measure the amount of water use.

Caution--For accuracy the sprayer should always be returned to the same spot and position for refilling.

e. *Calculate spray rate.* Spray rate is calculated as follows:

$$\text{Gallons per acre} = \frac{\text{gallons sprayed x 43,560 square feet per acre}}{\text{swath width (feet) x swath length (feet)}}.$$

The formula can be used to calibrate any type of spray or granular application equipment, including aerial, where the amount of material applied on the calibration course is measured.

EXAMPLE

A field sprayer with a 30 foot effective spray swath is operated for a distance of ¼ mile (1,320 feet) and 20 gallons of water are needed to refill the tank. What is the spray rate?

$$\text{Gallons per acre} = \frac{20 \times 43{,}560}{30 \times 1{,}320} = 22 \text{ gpa.}$$

The key information developed by calibration is the *number of gallons sprayed on 1 acre of land.* From this you can calculate how many acres worth of water the spray tank holds and how much chemical concentrate is needed in the tank to get the desired amount of chemical on the sprayed area. These calculations will be discussed in the section on computing chemical mixes.

Be sure to recheck your calibration after the chemical has been added to the tank. It may be slightly different than it was with plain water. If it varies much from your original figures, a slight adjustment in sprayer speed or pressure may be needed to get the proper amount of chemical applied.

4) *Band Application.* Unless otherwise stated, label rates are for ground actually sprayed. For band application, the specified rate will be applied to the treated area but only a fraction as much chemical will be used per acre.

Calibration for band spraying can be performed the same as broadcast, except only a fraction of the area is treated. The band width desired can be attained by adjusting the height of the nozzles above the ground. It is important to distribute the spray evenly across the band. "Even spray" tips are used for this purpose.

Steps for calibrating band sprayer in the field are:

Step 1. Fill spray tank with water;

Step 2. Select field speed to be used;

Step 3. Adjust pressure within recommended range for nozzles used;

Step 4. Measure band width in feet and multiply by number of bands treated at one time;

Step 5. Spray a measured distance in the field to be treated;

Step 6. Return to the filling point and measure the water needed to refill the tank;

Step 7. Calculate the spray rate on the band as follows:

$$\text{Gallons per acre} = \frac{\text{gallons used x 43,560}}{\text{treated width x distance}}.$$

EXAMPLE

A six row planter is equipped to spray a 10 inch band centered over 40 inch rows. This planter is run 1,320 feet through the field and it used 5 gallons of water. What is the spray application rate?

$$\frac{\text{10 inch bands x 6 rows}}{\text{12 inches per foot}} = 5 \text{ feet treated width.}$$

$$\text{gpa} = \frac{\text{5 gallons x 43,560}}{\text{5 foot width x 1,320 feet}} = 33 \text{ gpa on the bands.}$$

You therefore need to add an acres worth of chemical to each 33 gallons of water in the tank. If you have a 100 gallon tank you can treat 3 acres of band per full tank ($\frac{100}{33} = 3$). You should note, however, that the field acreage covered by a full tank will be $\frac{\text{40 inches x 3 acres}}{\text{10 inches}} = 12$ acres in this particular example.

5) *Nozzle Method.* The nozzle method for calibrating broadcast and band sprayers may be useful as either a primary method or as a quick check. Once the field speed (mph) and nozzle pressure (psi) have been determined you can collect the discharge from *one nozzle for one minute* with the sprayer operating at the selected pressure and calculate the spray rate using the following formula:

$$gpa = \frac{\text{ounces per minute (one nozzle) x 46.4*}}{\text{speed (mph) x nozzle coverage (inches)}}.$$

EXAMPLE A

A field sprayer with nozzles spaced 20 inches apart is operated at the desired pressure. After determining that all nozzles are spraying about the same amount, the discharge from one nozzle is collected for 1 minute and found to be 32 ounces. How many gallons per acre will be sprayed when the sprayer is operated at 4 mph?

$$\frac{32 \text{ ounces x } 46.4}{4 \text{ mph x } 20 \text{ inches}} = 18.5 \text{ gpa.}$$

EXAMPLE B

A band sprayer on a corn planter is set to spray a 10 inch band and the discharge from one nozzle is 30 ounces per minute at the desired pressure. What will be the spray rate when the planter is operated at 4 mph?

$$\frac{30 \text{ ounces x } 46.4}{4 \text{ mph x } 10 \text{ inches}} = 34.8 \text{ gpa on the band.}$$

Caution--When using the nozzle method for calibration it is especially important that all nozzles are spraying at the same rate.

Sprayers should be re-calibrated every day or two when in heavy use to check for nozzle wear. Re-calibrate every 8 hours if wettable powders are being used because they are more abrasive than other chemical formulations and cause faster nozzle wear.

B. Calibrating Hand Sprayers

Spray equipment with a single nozzle or 3 to 4 nozzle booms are used by home owners and researchers for lawn and garden care and for certain small plot work. Single high pressure nozzles attached to conventional sprayers are widely used for right of way and spot treatment spraying by commercial applicators, farmers and ranchers. Calibration of this equipment is simple but seldom done. Over application with this equipment is a common occurrence. The following procedures can be used to calibrate these types of equipment.

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*This constant applies when the discharge is measured in ounces per minute and one nozzle coverage is measured in inches. It is derived as follows:

$$\frac{43{,}560 \text{ square feet/acre x } 12 \text{ inches/foot x } 60 \text{ minutes/hour}}{5{,}280 \text{ feet/mile x } 128 \text{ ounces/gallon}} = 46.4.$$

Constants to use for other units of measure are:

milliliters - 1.57 pints - 742.5 gallons - 5,940

1) *Compressed Air Sprayers.*

Step 1. Mark out a square rod (16½ ft. x 16½ ft.)

Step 2. Put a known amount of water into the tank (2 qts. is usually enough);

Step 3. Pump the sprayer to 30-40 lbs. pressure if it has a gauge. If not, count the number of strokes used to pump up the sprayer;

Step 4. Spray the square rod, walking at the same speed you would use spraying a plot or yard;

Step 5. Measure the water remaining in the spray can and subtract this from the original amount;

Step 6. Compute the spray rate by the following formula:

Number of cups used x 10* = gpa.

2) *Pressure Hand Gun.* The high pressure hand gun is calibrated by measuring the time, (in seconds), needed to spray 1 square rod. The accuracy is increased if the time is measured on the plant species you plan to spray.

After the time to spray the square rod has been determined, spray into a container for the same amount of time. Measure the amount of water collected (cups) and multiply by 10 to find the spray rate in gallons per acre.

C. Computing Chemical Mixes

The label on chemical pesticides lists the amount of active ingredient (a.i.) or acid equivalent contained in the formulation. The actual amount is stated in terms of percent active ingredient by weight or the pounds of active ingredient per gallon. Herbicide rate recommendations are usually in terms of pounds of active ingredient per acre or volume of concentrate per acre. Insecticide recommendations may be in terms of pounds or volume per acre, ounces per 1,000 feet of row or volume per gallon of water.

1) *Computing Mixes as Pounds Per Acre.* Calibration of sprayers determines the amount of water applied to an acre under your operating conditions. Once the application rate is known, the amount of chemical needed can be calculated. Divide the sprayer tank capacity (gallons) by the application rate (gallons per acre) to find the number of acres a full tank will spray. Enough chemical is added to the tank to treat that many acres.

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*There are 160 square rods in an acre and 16 cups in a gallon. Dividing 160 by 16 gives the constant-10-used in the formula.

$$\text{Chemical required} = \frac{\text{acres sprayed x chemical rate (lb. a.i./acre)}}{\text{chemical concentration (lb. or \% a.i./unit)}}$$

EXAMPLE A

The sprayer has a 100 gallon tank and is calibrated to apply 20 gallons per acre. How much 2,4-D concentrate containing 4 pounds a.i. per gallon should be added to each tank if the recommended treatment is 2 pounds per acre.

$$\frac{\text{100 gal. tank}}{\text{20 gal/acre}} = \text{5 acres per tank.}$$

$$\frac{\text{5 acres/tank x 2 lb. a.i./acre}}{\text{4 lb. a.i./gal.}} = 2\tfrac{1}{2} \text{ gal. concentrate/tank.}$$

EXAMPLE B

You are using the same sprayer but the recommended rate is 2 pounds per acre of a 80% wettable powder.

$$\frac{\text{5 acres/tank x 2 lb. a.i./acre}}{\text{.80 a.i./lb. of concentrate}} = 12\tfrac{1}{2} \text{ lb. concentrate/tank.}$$

Be sure to read the chemical label to know how much active ingredient is contained in each gallon of liquid concentrate or pound of wettable powder to be sure the right amount is added to the tank. Add the chemicals after the tank is partly filled with water. Wettable powders should be made as a slurry in a bucket and then added to the spray tank to insure complete mixing.

If the acreage you plan to treat requires less than a full tank of water, add only enough water and chemical to treat the required acreage to reduce the amount of unused chemical mixture. Dispose of any unused chemicals in a way that will not harm the environment.

2) *Figuring Solutions as Percent.* Percent by weight--to determine how much chemical should be used to obtain a solution of given percent concentration by weight, use the following formula:

$$\text{Lb to use} = \frac{\text{\% by wt. desired x gal. final mix x wt. of water lb/gal.}}{\text{\% strength of chemical to be used}}$$

(1 gallon of water weighs 8.34 pounds)

EXAMPLE

How much concentrate containing 40% active ingredient should be added to 100 gallon tank of recommended treatment is a 0.25% (¼%) concentration by weight?

$$\text{Lb to use} = \frac{.0025 \times 100 \text{ gal.} \times 8.34 \text{ lb/gal}}{.40}$$

= 5.2 lb. commercial wettable powder as it comes from bag.

3) *Figuring Solutions as Parts Per Million Mix.*

a) *Parts per million mix (powder).* To determine how much wettable powder should be used to obtain a solution of a given concentration in parts per million, use the following formual:

$$\text{Lb to use} = \frac{\text{ppm desired} \times \text{gal. final mix} \times \text{wt. of water lb/gal}}{1{,}000{,}000 \times \% \text{ strength of chemical to be used}}$$

EXAMPLE

How much powder containing 40% active ingredient should be added to 100 gallon tank if recommended treatment calls for 1200 ppm active ingredient?

$$\text{Lb to use} = \frac{1200 \times 100 \text{ gal.} \times 8.34 \text{ lb/gal}}{1{,}000{,}000 \times .40}$$

= 2.5 lb. of 40% formulation as it comes from bag.

b) *Parts per million mix (liquid).* To determine how much liquid emulsifiable concentrate should be used to obtain a solution of a given concentration in parts per million, use the following formula:

$$\text{Gal to use} = \frac{\text{ppm desired} \times \text{gal. of final mix} \times \text{wt. of water lb/gal}}{1{,}000{,}000 \times \text{lb. active ingredient/gal}}$$

EXAMPLE

How much liquid emulsifiable concentrate containing 0.625 pounds of active ingredient per gallon should be added to a 100 gallon tank if the recommended treatment calls for 300 parts per million active ingredient of a liquid chemical?

$$\text{Gal to use} = \frac{300 \times 100 \text{ gal.} \times 8.34 \text{ lb/gal}}{1{,}000{,}000 \times 0.625 \text{ lb/gal}} = .4 \text{ gal.}$$

The recommendation also advises addition of an oil or surfactant (not both) at ½% by volume. How much oil to surfactant should be added:

Amount needed - ½% of 100 gal. or 0.0025 x 100 = .25 gal. or 1 qt.

4) *Figuring Chemicals for Small Plot Work.* When doing small plot work, very small amounts of chemical are used. It is convenient to both calibrate sprayers and calculate chemical amounts on a square rod basis. Table 2 will be useful in making these calculations. A formula to use is:

$$\frac{\text{Amount of concentrate for 1 lb. a.i. x rate/acre}}{\text{160 sq. rods/acre}}$$

= amount to spray 1 sq. rod.

Table 2. Conversion table for liquid and dry measure.

	ML	Teaspoon	Tablespoon	Ounce	Gram
Milliliter or c.c.	1				
Teaspoon	5	1			
Tablespoon	15	3	1		
Ounce (fluid)	29.6	6	2	1	
Cup	236.5	48	16	8	
Pint	473	96	32	16	
Quart	946	192	64	32	
Liter	1000	203	68	34	
Gallon	3785	768	256	128	
Gram				.035	1
Ounce				1	28.4
Pound				16	454
Kilogram				35	1000

EXAMPLE

You have calibrated your compressed air sprayer and find you are applying 1 quart per square rod. You want to apply a chemical weed control on a lawn at the rate of 2 pounds per acre. The chemical concentrate contains 4 pounds a.i. per gallon (1 lb. per qt.). How many teaspoons of concentrate are needed for each square rod treated? From Table 2 there are 192 teaspoons per quart, therefore,

$$\frac{\text{192 tsp/lb x 2 lb/acre}}{\text{160 sq. rod/acre}} = \text{2.4 tsp/sq rod.}$$

You would probably add 2½ teaspoons of concentrate to each quart of water in the spray tank in this example.

D. Calibrating Granular Applicators

Granular applicators can be calibrated in a manner similar to those for sprayers. The amount of granules applied by applicators depends on the size of the metering opening, speed of travel, field roughness, and the flow rate of the granule which is affected by size, shape, and density of the granules, temperature, and humidity. Because of such variables, it is difficult to predict a certain rate at a certain setting. Use the manufacturer's instructions as a guide, but run a check by actually catching the granule discharge per row from a measured area. The refill method is not recommended for granules because the actual chemical must be used and trial settings could result in over application and environmental damage.

1) *Field Calibration.*

Use the following calibration steps for broadcast or band applicators.

1. Adjust orifice (delivery openings) on applicator unit(s) at manufacturer's setting and fill hopper(s) with granules to be applied.

2. Set tractor or unit speed as it will be operated in the field.

3. Operate the unit over a measured distance of several hundred feet in the field to be treated. Collect the granules from each discharge tube.

4. Accurately weigh the amount of chemical delivered by each outlet and add together. (All should be equal.)

5. Calculate the area treated. For herbicides, multiply individual band width (in feet) times number of rows times distance traveled (in feet). For insecticides, the area treated is the row spacing (feet) times distance treated times number of rows.

6. From No. 4 and No. 5 calculate the amount of granules applied per acre (application rate) as follows:

$$\text{Pounds/A (granules)} = \frac{43{,}560 \times \text{pounds granules applied over course}}{\text{area of measured course in square feet}}$$

This value is pounds per acre (lb/A) of granular formulation applied. To determine the amount of active ingredient applied, multiply lb/A by percent active ingredient.

Lb/A (a.i.) = lb/A granules x percent active ingredient.

7. Complete calibration by repeatedly adjusting and retesting until desired quantity of granules are delivered. Record the proper setting for future reference. To figure how much chemical should be collected to get the desired application rate use the following formula:

$$\text{Lb granules} = \frac{\text{lb a.i./acre desired x sq. ft. treated}}{\text{\% a.i. in chemical x 43,560}}$$

EXAMPLE

A granular applicator treats bands 1 foot wide on three rows (3 rows x 1 foot = 3 feet treated). When driven over a distance of 870 feet each tube delivers 4/10 pound of granules (3 rows x 4/10 pound = 1.2 pounds) at the setting used.

$$\text{Lb/A} = \frac{\text{43,560 x 1.2 lb granules}}{\text{3 ft. x 870 ft.}} = \text{20 lb/A granules.}$$

If the active ingredient concentration of the granules was 20%, the rate of active material applied per acre would be:

Lb/A = 20 lb/A granules x .20 = 4 lb/A active ingredient.

If the desired rate is 3 pounds a.i. per acre the amount of granules that should be collected on the above course is:

$$\frac{\text{3 lb a.i./acre x 3 x 870}}{\text{.20 x 43,560}} = \text{.9 lb granules}$$

2) *Shop Calibration.* PTO driven granular applicators can be calibrated in the shop by calculating the distance that will be traveled in 1 minute, then collect granules for 1 minute with the applicator running at field speed. Values obtained in this manner can be substituted in the above formulas.

EXAMPLE

The applicator will be run at 3 mph in the field and the amount of granules collected in 1 minute at this speed is 1/8 pound (2 ounces) per tube on a three row distributor. The band width is 12 inches. The application rate will be:

$$\frac{\text{43,560 x (3 x 1/8)}}{\text{3 x (3 x 88)*}} = \text{20.6 lb. formulation per acre.}$$

3) *Calibrating Granular Insecticides.* The label on some granular insecticides recommends applying so many ounces of formulation per 1,000 feet of row. Calibration is complete when the desired amount of formulation is collected in the prescribed distance.

Some insecticide labels give the recommendation in terms of pounds of chemical per acre on 40 inch rows. A band width may or may not be specified. When the recommendation is given in these terms, the treated area in step 5 above is based on the row width, 40 inches.

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*From page V-16, mph x 88 = feet per minute.

When the amount applied to each individual row is correct for 40 inch spacing it will also be correct for all other row spacings. If row widths are less than 40 inches, however, the total insecticide used will be increased by a factor obtained by dividing 40 inches by the new row width. Multiply the recommended rate by the factors shown in Table 3 to determine the rate for row spacings shown.

Table 3. Correction factors for chemical application rates when row widths are other than 40 inches.

Row Spacing	Correction Factor
40"	1.00
38"	1.05
36"	1.10
34"	1.18
32"	1.25
30"	1.33
24"	1.67
22"	1.82
20"	2.00

Many companies offer calibration tubes for their materials which can be attached to the distributor tube and will give a direct reading for that particular formulation. *These tubes can be used only for the designated chemical.*

E. Summary

Calibrating chemical sprayers is necessary to insure proper control of the target plant or insect without causing undue damage to non-target species or the environment in general. Proper use of chemical pesticides may determine whether they remain available to the general public in the future.

The methods of calibration discussed in this paper indicate a few ways chemical sprayers can be accurately calibrated. Other methods not discussed may be just as accurate or easy. It is important that you pick a method you understand and then use it every time you apply chemical pesticides.

SECTION IV

Sprayer Maintenance and Cleaning

Most trouble with sprayers can be traced to foreign matter that clogs screens and nozzles and sometimes wears out pumps and nozzles. The following suggestions will help reduce maintenance problems and prolong sprayer life.

1. *Use clean water.* As a rule of thumb use water that looks clean enough to drink. Water pumped directly from a well is best. Water from ponds or stock tanks will probably contain enough small particles to plug nozzle screens even though it looks clean. If it is necessary to use pond water, filter it before filling the tank.

2. *Keep screens in place.* A sprayer system usually has screens in three places; a course screen on the suction hose, a medium screen between the pump and the boom, and a fine screen in the nozzle. The nozzle screen should be fine enough to filter particles which will plug the tip orifice. A 100 mesh screen is normally adequate for nozzles. Screens should be in place at all times with one possible exception. When wettable powders are used it is difficult to keep them 100% in suspension and nozzle screens may have to be removed to prevent excessive clogging.

3. *Never use a metal object to clean nozzles.* To clean, remove the tips and screens and clean them in water or a detergent solution using a soft brush. The orifice in a nozzle tip is a precision machined opening. A thrust from a pin, knife or other metalic object can completely change the spray pattern and capacity of the tip.

4. *Flush sprayers before using them.* New sprayers may contain large amounts of metallic chips and dirt from the manufacturing process. Sprayers which have been idle for a while may contain bits of rust and dirt. Remove the nozzles and flush the sprayer with clean water. Clean *all* screens and nozzles thoroughly before trying to use the sprayer.

5. *Clean sprayer thoroughly after use.* After each day's use, thoroughly flush the sprayer with water, inside and out, to prevent corrosion and accumulation of chemicals. Be sure to discharge cleaning water where it will not contaminate water supplies, streams, crops, or other plants and where puddles will not be accessible to children, pets, livestock, or wildlife.

When changing chemicals or when finished spraying for the season, clean the sprayer thoroughly both inside and out. Some chemicals, such as 2,4-D, are particularly persistent in the sprayer and must be removed completely to prevent possible crop damage from other spraying operations. In other cases, chemical reaction may cause coagulation or loss of effectiveness of the chemical. For thorough cleaning between chemicals or at the end of the season, the following procedure is recommended.

a. Remove and clean all screens and tips in kerosine or a detergent solution using a soft bursh.

b. Mix one box (about 1/2 lb.) of detergent with 30 gallons of water in the tank. Circulate the mixture through the bypass for 30 minutes, then flush it out through the boom.

c. Replace the screens and nozzle tips.

d. Fill the tank about 1/3 to 1/2 full of water and add 1 quart of household ammonia to each 25 gallons of water. Circulate this mixture through the system for 5 minutes, allowing some to go out through the nozzles. Keep the remainder of the solution in the system overnight, and then run it out through the nozzles.

e. Flush the system with a tank full of clean water by spraying through the boom with nozzles removed.

6. *Prepare the system for off season storage.* When the pump is not in use, fill it with a light oil and store it in a dry place. If the pump has grease fittings, lubricate them moderately from time to time. Over lubrication can break seals and cause the pump to leak. Remove nozzles and screens and place them in a light oil for storage. Store the sprayer, hoses and booms in a dry shed.

APPENDIX TABLE 1: Conversion table, liquid measure.

	Ml	Tablespoon	Ounce	Cup	Pint	Quart	Liter	Gallon
Milliliter	1	0.067	0.033	0.0042	0.0021	0.0011	0.0010	0.0002
Tablespoon	15	1	0.50	0.0625	0.0312	0.0156	0.0149	0.0039
Ounce	29.57	2	1	0.125	0.0625	0.0312	0.0295	0.0078
Cup	236.5	16	8	1	0.50	0.250	0.2364	0.0625
Pint	473	32	16	2	1	0.50	0.474	0.125
Quart	946	64	32	4	2	1	0.943	0.250
Liter	1000	66.67	33.82	4.23	2.11	1.06	1	0.264
Gallon	3785	256	128	16	8	4	3.785	1

APPENDIX TABEL 2: Conversion table, dry measure.

	Gram	Ounce	Pound	Kilogram
Gram	1	0.0352	0.0022	0.0010
Ounce	28.35	1	0.0625	0.2835
Pound	453.6	16	1	0.4536
Kilogram	1000	35.27	2.20	1